

## A DIRECTIVE, BROADBAND, HIGH GAIN, ACTIVE ANTENNA SYSTEM

### CROSS-REFERENCE TO RELATED APPLICATION(S)

**[0001]** This application claims the benefit of U.S. Provisional Patent Application No. 60/629,688, filed on November 19, 2004.

### TECHNICAL FIELD

**[0002]** The disclosed embodiments, in general, relate to antenna systems and, in particular, to a broadband high-gain active antenna system.

### BACKGROUND

**[0003]** Most antenna developments up to this point have focused on traditional passive power transduction mechanisms, which rely on matching the radiation resistance of the antenna structure to the intrinsic impedance of free space and matching the output terminal impedance of the antenna structure to the input impedance of the receive system. There are numerous passive matching techniques and geometries that have been developed over the many years antenna technology has been in existence. Most of the innovation in antenna technology has been in the Aerospace, Defense, and Satellite Communications industries, while Commercial Radio and Television have long relied upon technology that has been available for over 40 years.

**[0004]** The current Television (TV) spectrum extends from 54 MHz to 806 MHz, corresponding to wavelengths ranging from 5.6 meters to 37 centimeters respectively. The more efficient, passive TV antenna designs commonly used can be relatively large and involve fairly elaborate geometries, to accommodate this range of frequencies. Typical TV antenna designs range from simple narrowband dipole structures, designed to be  $\frac{1}{2}$  of a wavelength at the frequency of interest, to more exotic broadband structures such as the log periodic dipole

array, which consists of several dipoles of decreasing size arranged coaxially. An efficient log periodic array can exceed 3 meters in length, with the longest dipole element reaching up to 2.7 meters. An array of this size can achieve gains as high as 5 dB to 9 dB over that of a dipole, which typically is around 2 dBi at a resonant  $\frac{1}{2}$  wavelength. This advantage over the dipole is a result of directive gain associated with the particular combination and relative phasing of the array elements. The single dipole has a bi-directional radiation/reception pattern and a bandwidth of around 30%, whereas the log periodic array is designed for a highly directional radiation/reception pattern and can accommodate bandwidths of several octaves.

**[0005]** Electrically small antennas are becoming more common in recent years due to size constraints imposed on many wireless consumer electronics. Also, there is a growing interest in this technology within the TV broadcast community as applied to indoor analog and digital TV reception and the indoor reception of Datacasting services. For example, a consumer residing in an apartment may require a high-gain directive antenna to receive broadcast DTV and/or an on-demand movie service via Datacasting, but does not have the space to utilize a typical log-periodic array. In this case, only an electrically small, broadband, high-gain antenna, with some directive selectivity for interference rejection, would be practical.

**[0006]** There are indoor antennas available to the consumer designed with these applications in mind, but most perform at low efficiencies and utilize active electronics to amplify the low-level antenna output power. Antennas such as these are often referred to as "active antennas" or "integrated active antennas", even though they are simply passive antennas with low-noise amplifiers (LNA) conditioning the output signal. The antenna section of these assemblies are acting as power transducers and still must be impedance matched to the LNA at all frequencies of interest to be useful. As a result, the indoor TV antenna designer must utilize broadband design techniques to achieve a broadband impedance match between the antenna output and the LNA input over several octaves of the TV frequency spectrum. If the additional requirement of

directivity/spatial selectivity is imposed, the design becomes much more challenging.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** Figure 1 illustrates an embodiment of the invention where an antenna system is in a directive configuration.

**[0008]** Figure 2 depicts a high-impedance, differential voltage amplifier circuit utilizing lossless feedback to maximize input impedance and linearity in accordance with another embodiment of the invention.

#### DETAILED DESCRIPTION

**[0009]** Illustrative embodiments of active antenna systems and methods are described below. The following explanation provides specific details for a thorough understanding of and enabling description for these embodiments. One skilled in the art will understand that the invention may be practiced without such details. In other instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments.

**[0010]** The terminology used in the description presented below is intended to be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain specific embodiments of the invention. Certain terms may even be emphasized below; however, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

**[0011]** Figure 1 depicts a high gain, broadband, directive active antenna system. This active antenna system consists of a pair of dipole probe elements

(a) connected to a highly linear, balanced amplifier with large input impedance (b), and a tuned scatter-plate assembly (c).

**[0012]** This antenna system employs an electric field (E-field) sensor active antenna approach, which combines an antenna probe element or elements to a high impedance voltage amplifier to produce an E-field sensing transduction mechanism. This approach presents advantages including broadband reception due to the lack of necessity for impedance matching between the antenna probe element(s) and the high input impedance voltage amplifier. Another advantage of this approach is that the size of the antenna probe elements are not dependent upon wavelength as passive antenna geometries are in order to accomplish resonance at the frequencies of interest.

**[0013]** Figure 2 depicts an amplifier embodiment, utilizing a high-impedance differential voltage amplifier design. Through the implementation of passive, lossless feedback, this differential voltage amplifier accomplishes scaleable gain, improved linearity, and greater input impedance than other common voltage amplifier designs.

**[0014]** The lossless feedback circuit comprises a wire-wound transformer (a) connected, as depicted, to a Field Effect Transistor (FET) (b) or any other high impedance transistor. The effective gain of the voltage amplifier is determined by the turn ratio of the transformer and can be scaled accordingly. To further reduce the noise contribution of the amplifier to the antenna system, a bias decoupling inductor (c) is used to decouple the noise contribution of the bias resistor network (d) from the input of the transistor (b). In one embodiment, a broadband inductor is implemented for (c) to ensure low noise operation across the entire VHF and UHF bands.

**[0015]** The inductance value of (c) can be chosen such that an RF voltage peaking effect is obtained at the transistor (b) input at a desired frequency. The combination of the lossless feedback voltage amplifier design and the E-field sensor active antenna approach results in an electrically small, active antenna

system with a broadband frequency response, scalable gain, very low amplifier noise contribution and wide dynamic range.

**[0016]** As a standalone active antenna system, the antenna probe element of Figure 1 and the amplifier subassembly of Figure 2 exhibit the bi-directional directive properties of a standard dipole of a fixed length. With the addition of a scatter-plate, this active antenna system becomes directive with separate, frequency-dependant, directive modes. Towards the lower half of the bandwidth of interest, the antenna system operates in a directive, capacitively-coupled loop mode, in which the fringing electric fields at the ends of the antenna probe elements, capacitively couple to the scatter-plate creating a directive loop effect. Towards the upper half of the bandwidth of interest, the wavelength is small enough relative to the design geometry, such that the antenna system operates in a reflector mode.

**[0017]** The scatter-plate can be tuned such that these separate directive modes occur at convenient areas of the RF frequency spectrum. The tuning mechanisms are: 1) distancing of the scatter-plate from the driven elements and 2) the effective inductance of the scatter-plate. The scatter-plate's effective inductance can be affected by material properties and geometry. Other means of achieving directivity using the antenna probe element and amplifier subassembly include: combining multiple subassemblies into arrays (fixed or steerable); combining a driven subassembly with a non-driven director element; and combining a driven subassembly with any number of non-driven director elements and a scatter-plate/reflector assembly.

**[0018]** In the case of an active antenna system designed for broadband TV reception, such as the embodiment illustrated in Figure 1, the scatter-plate (c) dimensions and proximity to the antenna subassembly (a) & (b) are chosen such that the antenna exhibits a minimum front to back directive ratio (F/B) of +8dB at High VHF and UHF frequencies. In this case, the overall length of the antenna probe element and amplifier subassembly is 22" and the 4.5" by 27" scatter-plate is located 3" from the center line of the antenna subassembly. It is possible to

achieve similar directive properties at lower frequencies, such as Low VHF TV and FM radio channels, if the scatter-plate geometry is tuned appropriately for those frequencies.

**[0019]** Unless the context clearly requires otherwise, throughout this application, the words "comprise," "comprising," and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." As used herein, the terms "connected," "coupled," or any variant thereof, means any connection or coupling, either direct or indirect, between two or more elements; the coupling of connection between the elements can be physical, logical, or a combination thereof.

**[0020]** Additionally, the words "herein," "above," "below," and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the above Detailed Description using the singular or plural number may also include the plural or singular number respectively. The word "or" in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list.

**[0021]** The above detailed description of embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

**[0022]** The teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

**[0023]** Changes can be made to the invention in light of the above Detailed Description. While the above description details certain embodiments of the invention and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Details of the antenna system may vary considerably in its implementation details, while still being encompassed by the invention disclosed herein.

**[0024]** Those skilled in the relevant art will appreciate that aspects of the invention can be practiced with other communications including: Internet appliances, hand-held devices (including personal digital assistants (PDAs)), wearable computers, all manner of cellular or mobile phones, multi-processor systems, microprocessor-based or programmable consumer electronics, set-top boxes, network PCs, mini-computers, mainframe computers, and the like. Indeed, the terms "computer," "host," and "host computer" are generally used interchangeably herein, and refer to any of the above devices and systems, as well as any data processor.

**[0025]** All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

**[0026]** While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. Accordingly, the inventors reserve the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the invention.